PFR SPTS No. 18153

Evaluation of selected horticultural crops for the Post-Quake Farming Project

Ward R, Clothier B

June 2019















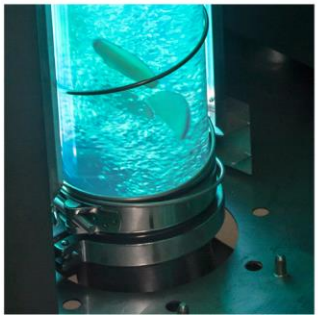


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Executive summary

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We first carried out a generic assessment of the suitability of the Post-Quake Agriculture Project's area for horticultural crops. These generic criteria revealed that potentially there are 41,515 ha of land that would be suitable for horticulture. The total area covered by the Project is about 466,000 ha.

We then used Virtual Climate Station Network (VCSN) data of long-term weather records to provide detailed assessments of six horticultural crops across four sub-regions in the Post-Quake Project area.

For these four sub-regions we associated two or three VCSN stations with each sub-region.

This stratification included:

- North of Kaikoura
- Kaikoura plains
- Waiau and surrounds
- Cheviot and Conway flat.

For each sub-region, the associated VCSN data were used to assess suitability of the following crops:

- Apples
- Kiwifruit
- Wine grapes
- Blueberries
- Hazelnuts and walnuts
- Avocados.

For these sub-regions, the crops that we consider suitable are:

- North of Kaikoura – apples, grapes, hazelnuts and walnuts
- Kaikoura plains – apples, grapes (coastal), hazelnuts and walnuts
- Waiau and surrounds – apples (Waiau only), grapes (Waiau only), hazelnuts and walnuts
- Cheviot and Conway flat – apples, hazelnuts and walnuts.

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1 Introduction

Plant & Food Research were asked to carry out a desktop study assessing the suitability of different horticultural and plant-based foods in response to land and weather characteristics in selected areas of North Canterbury.

The Suitability Assessment which this report summarizes was undertaken for the Post Quake Farming Project, a programme to support the recovery of farming businesses and future land use decisions in the area affected by the Kaikoura Earthquakes. This programme is jointly funded by MPI through the Earthquake Recovery Fund with significant contributions from Beef+Lamb NZ, and Environment Canterbury.

Answer to specific questions were sought, and these included:

Which crops suit the conditions present in each area?

- What mitigation might be required?

The first stage of the project was to facilitate community involvement through two workshops. The first of these was held in Kaikoura on 1 April 2019, and the second at Spotswood the day after. The goals of these workshops were to:

- Build community involvement and ensure subsequent buy-in
- Establish boundaries of the study
- Ensure the direction was aligned with what the community is looking for.

As a result of this community engagement a list of suitable crops was agreed upon, and this included:

- Apples
- Kiwifruit
- Wine grapes
- Blueberries
- Hazelnuts and walnuts
- Avocados.

This desktop assessment of suitability was carried out in two phases. These were:

- Firstly, a broad GIS sweep over the entire area (Figure 1) for an initial screening of the suitability for horticultural crops according to four generic suitability criteria
- Secondly, a more detailed analysis performed for ten Virtual Climate Station Network locations (VCSN - provided by NIWA), ranging from Kekerengu in the north to Cheviot in the south (Figure 1, Table 1). These analyses considered the six crops listed above.

In Figure 1 the extent of the Post-Quake Agricultural Project area is shown by the red quadrilateral (Table 1). We then selected 10 VCSN stations to be spatially representative and these provide a 46-year weather record for the 10 locations. The VCSN data are on a 5 x 5 km grid layout, so that each VCSN station is considered to be representative of the 25 km^2 area.

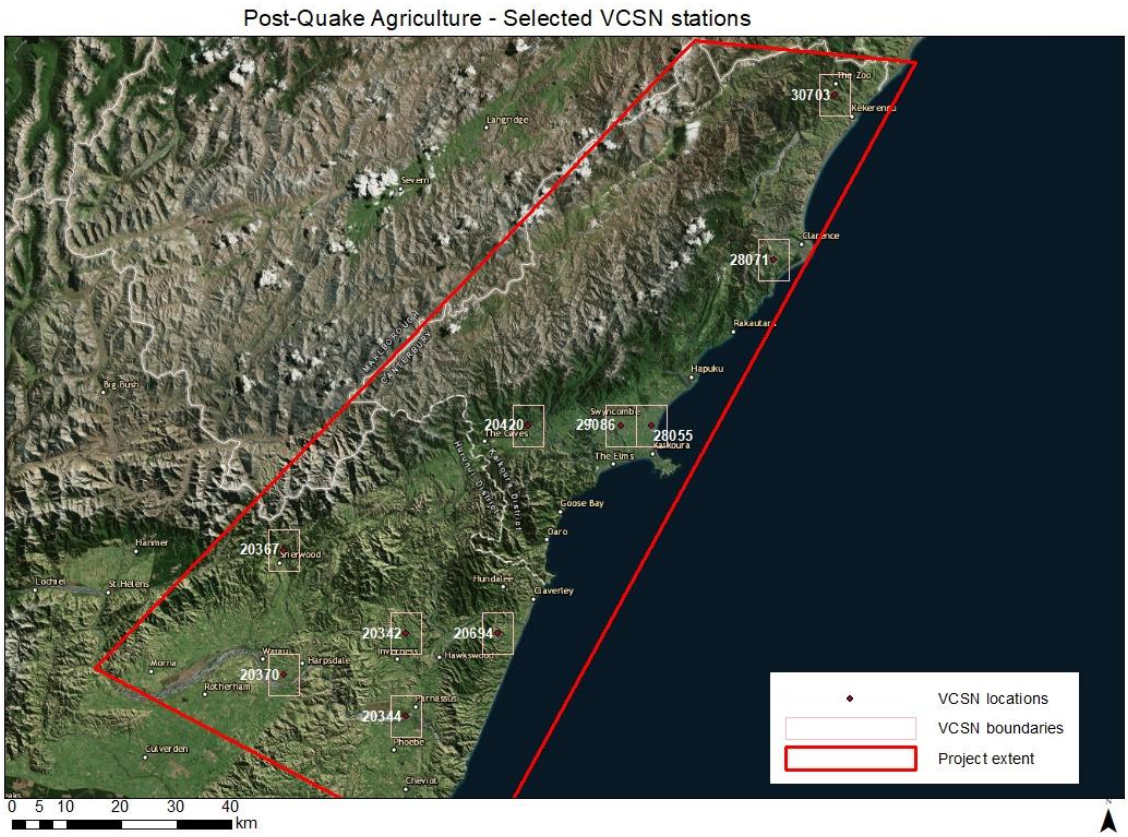

Figure 1. Overview of the extent of the Post-Quake Agriculture Project area showing the ten NIWA Virtual Climate Station Network (VCSN) locations used for detailed analysis.

Table 1. Details of the ten selected Virtual Climate Station Network (VCSN) locations. The VCSN data were provided by NIWA (Dr Andrew Tait, *pers. comm.).*

VCSN station	Latitude	Longitude	Approximate Location
20342	-42.625	173.275	Leader Valley
20344	-42.675	173.275	North of Cheviot
20367	-42.525	173.075	Lyford
20370	-42.675	173.075	Waiau
20420	-42.375	173.475	Inland Road
20694	-42.625	173.425	Conway Flat
28055	-42.375	173.675	Kaikoura plains, coastal
8071	-42.175	173.875	Clarence
29086	-42.375	173.625	Kaikoura plains, inland
30703	-41.975	173.975	Kekerengu

2 Broad GIS assessment

A broad sweep was conducted to assess the general suitability for horticulture based on four criteria:

- Good quality land comprising Land Use Capability (LUC) classes 1-3, 4s-7s (Manaaki Whenua Landcare Research; https://lris.scinfo.org.nz/layer/48076-nzlri-land-use-capability/)
- Land of slope of less than 8°, although here we considered slopes up to 15° may even be suitable for some horticultural crops, as evidenced by the vineyards to the north of Waipara (Manaaki Whenua Landcare Research; https://lris.scinfo.org.nz/layer/48081-lenz-slope/)
- Sufficient warmth to enable fruit maturity with Growing Degree Days base 10°C (GDD_{10}) of at least 800 degree days. The detailed VCSN analysis generally gives lower GDD_{10} values than the broad GIS sweep (NIWA; https://www.niwa.co.nz/climate/research-projects/national-and-regional-climate-maps Dr Andrew Tait, *pers. comm.*)
- A Frost Free Period (FFP) of at least 200 days (NIWA) so that frosts do not interfere with either flowering in spring, and harvest in late summer (NIWA; https://www.niwa.co.nz/climate/research-projects/national-and-regional-climate-maps. Dr Andrew Tait, *pers. comm.*).The detailed VCSN analysis later on generally gives higher FFP values than the broad sweep using GIS. We consider that the VCSN data are the more reliable, for they are interpolated to a 5 x 5 km grid from actual NIWA weather stations.

A map of the LUC classes that we consider to be generically suited to horticulture is presented as Figure 2. There are large tracts of LUC Class 2 and 3 land, especially around the Waiau and the Parnassus-Cheviot Basins, the Conway Flats, and the Kaikoura Peninsula.

Lands with a slope of less than 15° are shown in Figure 3. Many areas within the project boundary have lands flat enough in general to support horticulture.

A regional map of warmth, as indicated by GDD_{10}, is presented as Figure 4. The coastal regions, and most of the Waiau and Parnassus-Cheviot Basins have GDD_{10} values exceeding 800 degree days.

The FFP values are shown in Figure 5. The coastal regions all have frost-free periods exceeding 200 days, except for some of the elevated parts of the Kaikoura Peninsula. The inland basins have shorter FFPs, and so there may be some constraints with certain horticultural crops there. This is discussed in more detail later using weather data from the VCSN stations.

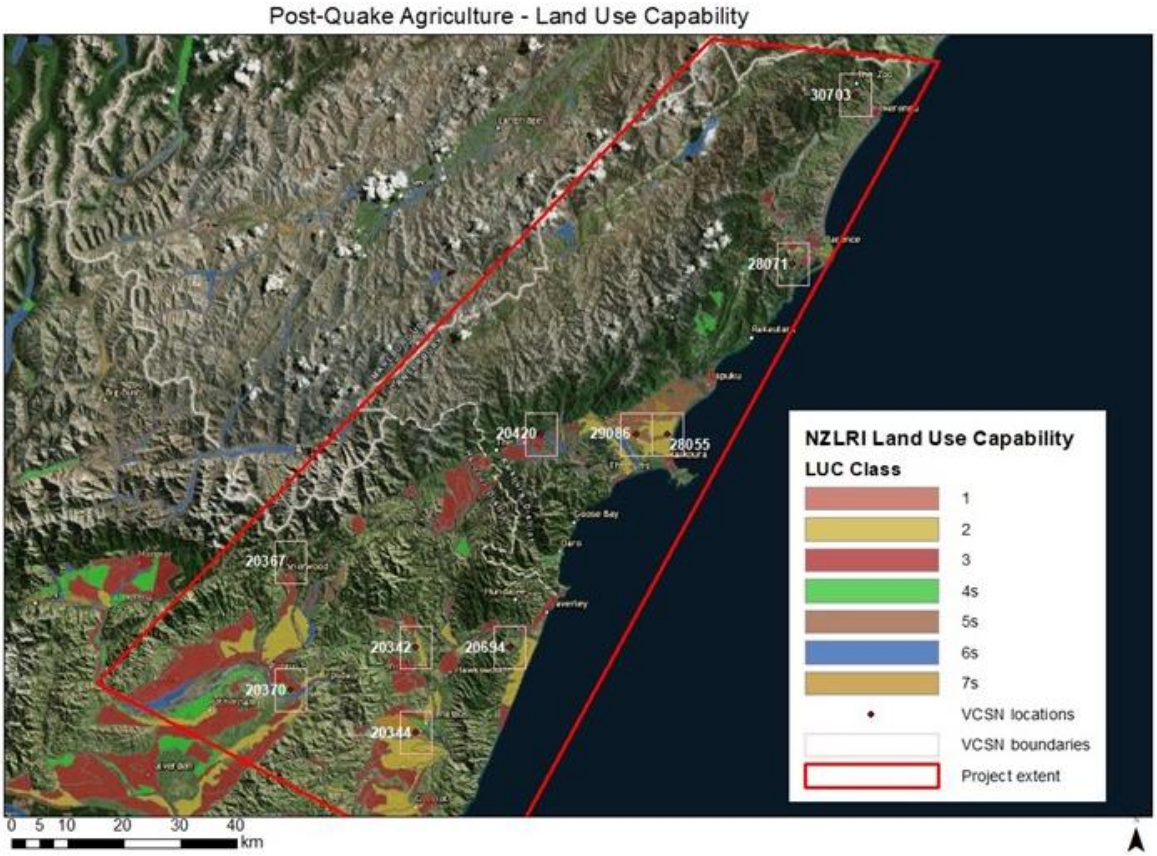

Figure 2. Land Use Capability (LUC) classes across the Kaikoura-Waiau region.

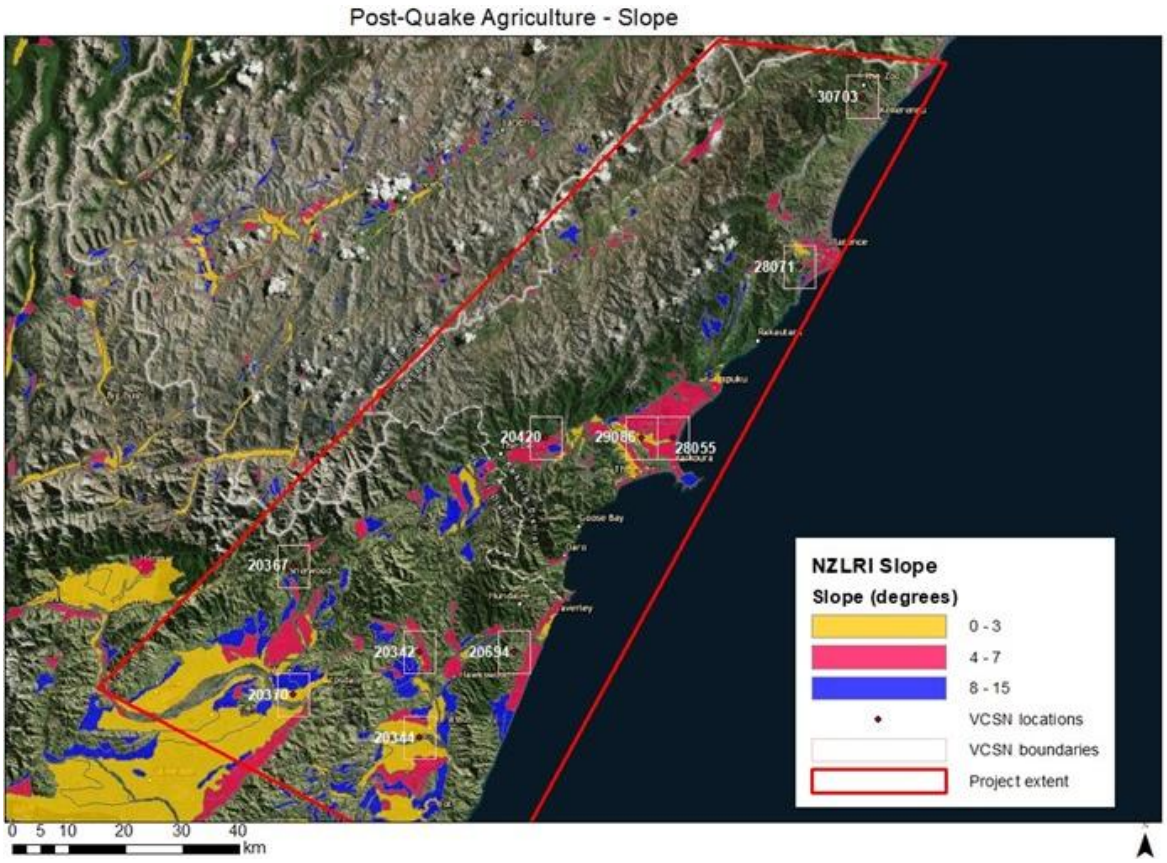

Figure 3. Slope class of land within across the Kaikoura-Waiau region.

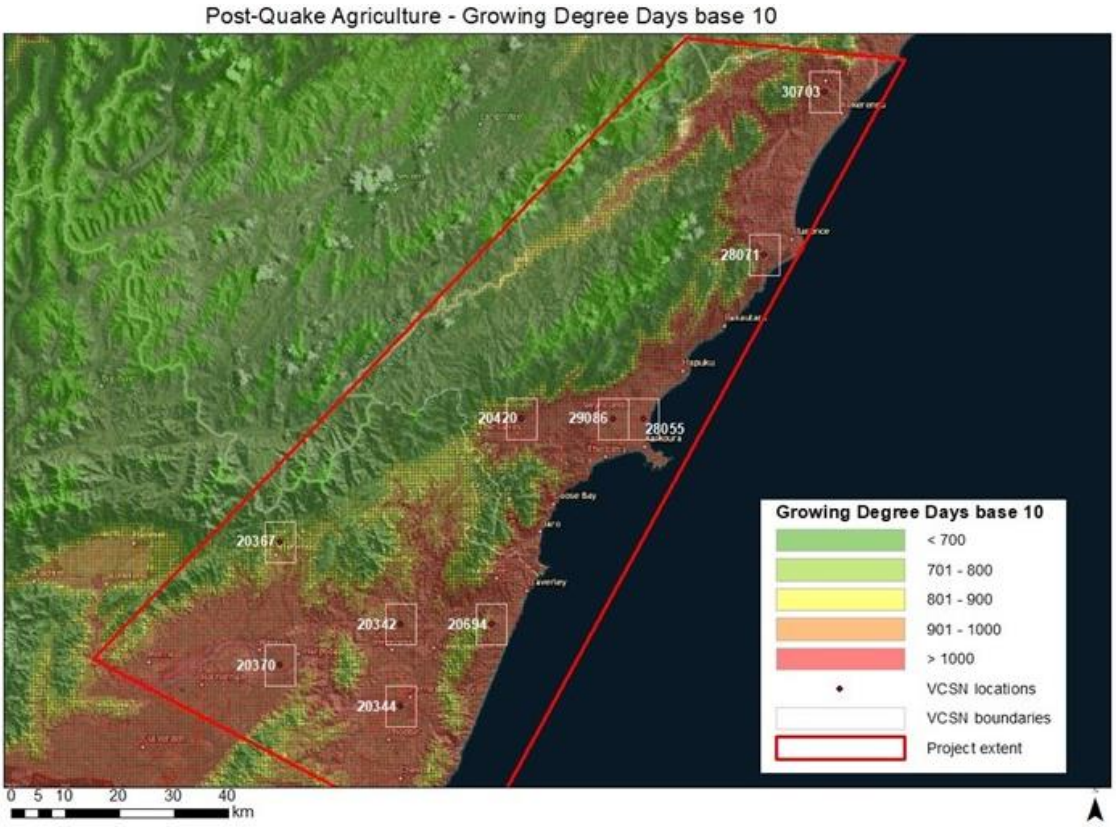

Figure 4. Annual warmth in terms Growing Degree Days base 10°C (GDD_{10}) across the Kaikoura-Waiau region. Virtually all the VCSN stations appear to have high GDD_{10} exceeding the generic criterion of 800 degree days.

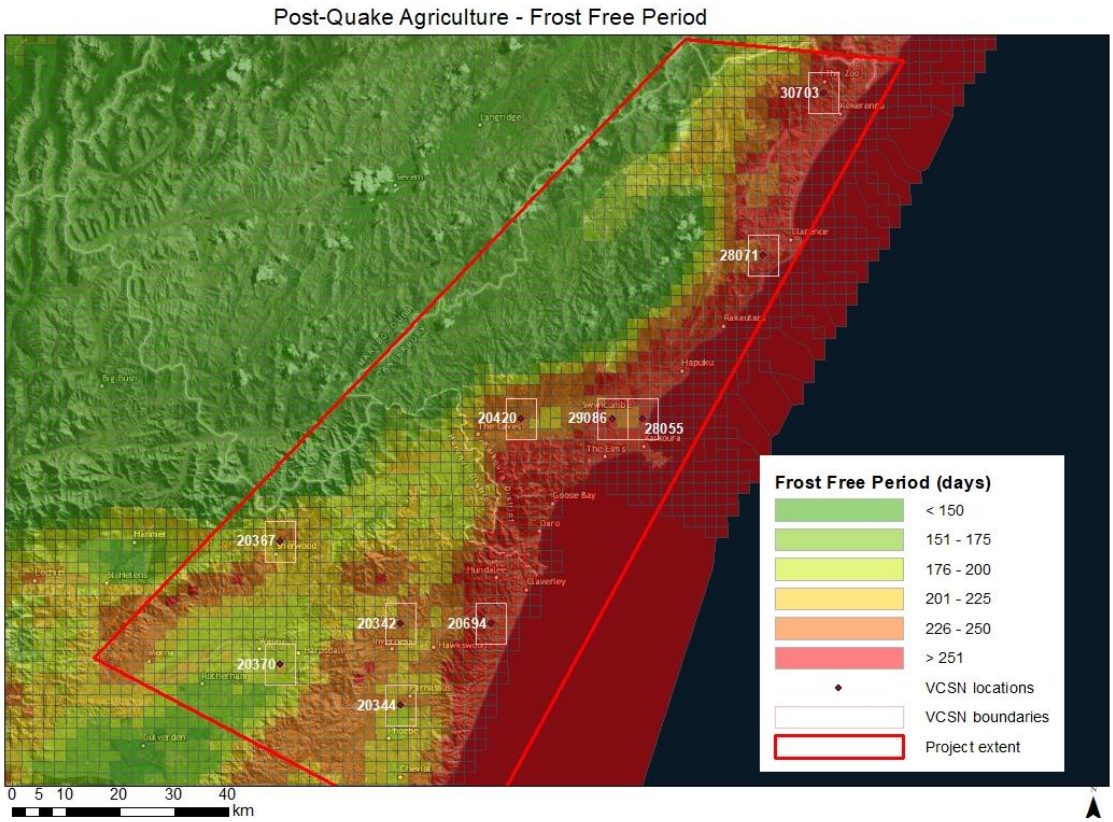

Figure 5. The Frost Free Period (FFP) across the Kaikoura-Waiau region. While the coastal areas have long FFPs, the inland areas show shorter FFPs which may pose challenges for some horticultural crops.

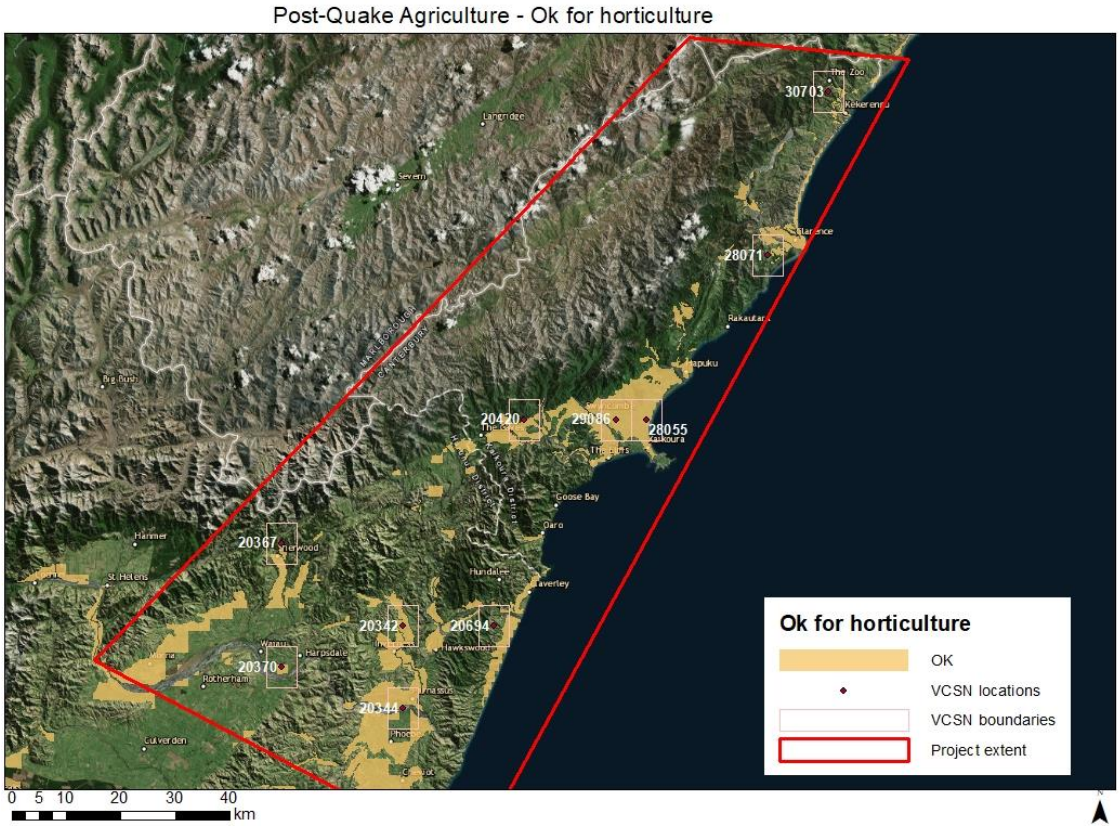

Figure 6. The overlap of all four generic suitability criteria for horticultural crops in general across the Kaikoura-Waiau region. We have considered land with slopes up to 15°. The area that appears suitable for horticulture inside the red quadrilateral is 41,515 ha.

From the four maps of these generic criteria (Figures 2 – 5), we produced a map of the areas where all four criteria are met (Figure 6). The overlap area of this intersection is 41,515 ha, and is distributed along the coast, and across the Waiau and Parnassus-Cheviot basins. The total area covered by the Post-Quake Project is 466,000 ha.

This broad GIS sweep provides an illustrative overview of the potential for horticulture in this region. Below, we use detailed analyses of long-term 46-year VCSN weather records from (Figure 1) to assess the specific suitability for the seven crops listed earlier.

3 Detailed analyses

To simplify our description of the detailed analyses we have carried out using the VCSN data, we have grouped the whole Post-Quake region into four sub-regions and we have associated two, or three, VCSN stations with each sub-region. This stratification is listed below:

- North of Kaikoura – VCSN 30703, 28071
- Kaikoura plains – VCSN 20420, 29086, 28055
- Waiau and surrounds – VCSN 20367, 20370
- Cheviot and Conway flat – VCSN 20342, 20694, 20344.

For each sub-region, the associated VCSN data were used to assess suitability the following crops:

- Apples
- Kiwifruit
- Wine grapes
- Blueberries
- Hazelnuts and walnuts
- Avocados.

3.1 North of Kaikoura

In the coastal strip to the north of Kaikoura, we have two associated VCSN stations. These are VCSN 30703, near Kekerengu, and VCSN 28071 near Clarence. The general climate statistics are presented in Table 2 for these stations.

We note an apparent anomaly for VCSN 28071 where the FFP for a -2°C event is 383 days, being longer than 1 year. This is a calculation artefact, as there is only one time where there has been a frost that cold in two consecutive years.

Table 2. General climate statistics for the Virtual Climate Station Network (VCSN) locations 28071 and 30703 for the region north of Kaikoura.

VCSN	28071	30703
Chill hours, April-September (T < 7°C)		
Mean	1438	1506
20th percentile	1200	1271
46-year minimum	970	1083
Chill hours, April-September (T < 7.2°C)		
Mean	1521	1585
20th percentile	1286	1345
46-year minimum	1047	1158
Growing Degree Days base 10°C, October-April		
Mean	964	979
20th percentile	885	891
46-year minimum	739	740
Spring and autumn frosts (0°C)		
Mean date of first autumn frost	July 1	June 25
20th percentile first autumn frost	June 15	June6
46-year earliest frost	May 25	May 2
Mean date of last spring frost	July 25	August 7
80th percentile last spring frost	August 16	August 30
46-year latest frost	September 1	October 6
Mean frost-free period	341 days	322 days
20th percentile frost-free period	311 days	287 days
46-year minimum frost-free period	281 days	263 days
Spring and autumn frosts (-2°C)		
Mean date of first autumn frost	July 5	July 4
20th percentile first autumn frost	June 29	June 22
46-year earliest frost	June 29	June 16
Mean date of last spring frost	July 6	July 9
80th percentile last spring frost	July 10	July 19
46-year latest frost	July 18	August 16
Mean frost-free period	383 days	347 days
20th percentile frost-free period	383 days	324 days
46-year minimum frost-free period	383 days	310 days

3.1.1 Apples

There is sufficient winter chill north of Kaikoura, with there being on average more than 1500 hours <7.2°C, exceeding the criterion needed for apples of >500 chill hours at <7.2°C (Table 2).

Also there is sufficient summer warmth for apple growing, with the October to April GDD_{10} being about 890 degree days (Table 2), exceeding the criterion for apples of 800 hours. Furthermore in the critical period of the first 50 days after flowering there is a GDD_{10} of about 185 degree days (Table 3), which exceeds the apple-growing criterion of 120 degree days.

There is minimal risk of frost, either after flowering or before harvest, at Kekerengu (VCSN 30703), but some frost protection will be needed for Clarence (VCSN 30703). We compare here, and elsewhere, the degree of frost risk with two existing apple growing regions: the established region of Nelson, and the merging region of Central Hawke's Bay. This degree of frost risk here of about 40% is in between that of Nelson (16%) and that of Central Hawke's Bay (56%), where apples are grown commercially.

Table 3. Apple growing criteria for the Virtual Climate Station Network (VCSN) locations 28071 and 30703 for the region north of Kaikoura.

VCSN	28071	30703
Mean date of apple flowering	October 23	October 23
Probability of frost after flowering	39%	0%
Mean date of apple harvesting	March 30	March 29
Probability of frost before harvest	39%	0%
Mean GDD_{10} for the first 50 days after flowering	185	188

Our analyses would suggest that the coastal area north of Kaikoura is suitable for apple growing.

3.1.2 Kiwifruit

There is in this coastal area north of Kaikoura sufficient winter chill to ensure adequate flowering for kiwifruit. Kiwifruit require the mean May-July temperature to be less than 11.7-15°C, depending on cultivar and whether or not Hi-Cane® is applied to break dormancy (Table 4).

Kiwifruit require summer warmth to enable fruit maturation, and the GDD_{10} should exceed 1100 degree days between October and April. North of Kaikoura the summer GDD10 is, on average, just 970 degree days (Table 2), and this is considered insufficient for the successful growing of kiwifruit.

As with apples, there is a low frost risk at VCSN station 30703 (Kekerengu), but frost protection would be needed for Clarence (VCSN 38071) (Table 4).

Table 4. Kiwifruit growing criteria for the Virtual Climate Station Network (VCSN) stations 28071 and 30703 for the region north of Kaikoura.

VCSN	28071	30703
Mean temperature from May to July	8.8°C	8.5°C
Mean date of green kiwifruit budbreak	September 14	September 14
Probability of frost after budbreak (green-fleshed kiwifruit)	39%	6%
Mean date of gold kiwifruit budbreak	September 14	September 14
Probability of frost after budbreak (gold-fleshed kiwifruit)	39%	6%

Because of the lack of summer warmth, with the October-April GGD10 being just 970 degree days, and less than the kiwifruit criterion of 1100, we consider kiwifruit to be unsuitable for the coastal region north of Kaikoura.

3.1.3 Wine grapes (Pinot noir and Sauvignon blanc)

For grape growing in the coastal area north of Kaikoura there is sufficient winter chill, as the mean July temperature is about 7.5°C, being less than the criterion for grapes of 12°C (Table 5).

There no frost risk in spring after budbreak for either grape variety (Table 5), and there is no risk of excessive summer heat (>40°C) (Table 5).

For successful maturation of the grape berries and to avoid berry splitting and botrytis bunch rot, there should not be excessive rains in autumn, and ideally there should be less than 70 mm of rain per month over March and April. The rainfall north of Kaikoura is marginally above this value (Table 5).

Summer warmth is required for berry maturation, with the GDD_{10} being between 800 and 1000 degree days for Pinot noir, and 850-1050 degree days for Sauvignon blanc. The GDD_{10} values for the growing seasons of these varieties are 910-930 (Table 5), and so are mid-range for suitability.

Table 5. Wine grape growing criteria for the Virtual Climate Station Network (VCSN) stations 28071 and 30703 for the region north of Kaikoura.

VCSN	28071	30703
Mean temperature in July	7.5°C	7.3°C
Mean monthly rainfall for March and April	83.8mm	75.3mm
Mean number of summer days with maximum temperature above 40°C	0	0
Mean autumn date where temperatures drop below 13°C	April 13	April 12
Mean budbreak date for Pinot noir	October 7	October 7
Mean GDD_{10} for Pinot noir growing season	915	929
Mean budbreak date for Sauvignon blanc	October 9	October 10
Mean GDD_{10} for Sauvignon blanc growing season	912	924
Risk of -1°C frost after budbreak (Pinot noir)	0%	0%
Risk of -3°C frost after budbreak (Pinot noir)	0%	0%
Risk of -1°C frost after budbreak (Sauvignon blanc)	0%	0%
Risk of -3°C frost after budbreak (Sauvignon blanc)	0%	0%

The area north of Kaikoura would appear moderately suitable for grape growing, and care would need to be taken with autumn rains, and somewhat cool summer seasons.

3.1.4 Blueberries

Blueberries require over 800 chill hours less than 7.2°C between April and September. In the area north of Kaikoura this criterion is well exceeded, with the average number of chill hours being about 1500 (Table 2).

There is sufficient summer warmth, with the October-April GDD_{10} being over 950 degree days (Table 2), thus exceeding the criterion for blueberries of 600 degree days.

Blueberries do not, however, respond well to cool summer days less than 18-19°C. Some 20% of the time there are 30-45 days a year when maximum daytime summer temperatures do not exceed 18-19°C (Table 6). Tunnel houses, or covered structures, could be used to reduce the impact of these cool days.

Table 5. Summer maximum daily-temperature criteria for blueberry growing for the Virtual Climate Station Network (VCSN) stations 28071 and 30703 for the region north of Kaikoura.

VCSN	28071	30703
Percentage of years with at least one summer day with maximum temperature less than 18°C	100%	100%
80^{th} percentile of summer days with maximum temperature less than 18°C	34	30
Percentage of years with at least one summer day with maximum temperature less than 19°C	100%	100%
80^{th} percentile of summer days with maximum temperature less than 19°C	44	39

Because of cool summer days in this coastal region north of Kaikoura, it is considered that the area is not suitable for the outdoor growing of blueberries. It would also seem marginal for the growing of blueberries under protective covers.

3.1.5 Hazelnuts and walnuts

In this area north of Kaikoura, there are sufficient winter chill for hazelnuts, being some 1500 hours less than 7°C between April and September (Table 2), which exceeds the 1200 hours required by hazelnuts and walnuts with low to moderate chill requirements. There would need to be careful selection of the walnut cultivars, and some have high winter chill requirements exceeding 1600 hours (Table 7).

Nut crops require summer warmth, with GDD_{10} requirements of at least 800 degree days. The summer GDD_{10} here of 970 degree days (Table 2) well exceeds this criterion.

There is no risk from either spring or autumn frosts of greater than -2°C (Table 7).

Table 6. Chill hour and frost risk criteria for hazelnuts and walnuts for the Virtual Climate Station Network (VCSN) stations 28071 and 30703 for the region north of Kaikoura

VCSN	28071	30703
Probability of >400 winter chill hours	100%	100%
Probability of >800 winter chill hours	100%	100%
Probability of >1200 winter chill hours	80%	89%
Probability of >1600 winter chill hours	30%	37%
Probability of autumn frost before March 15	0%	0%
Probability of spring frost after October 15	0%	0%
Probability of spring frost after November 1	0%	0%

The area north of Kaikoura appears well suited to nut crops, although cultivar selection for walnuts would be needed to avoid those cultivars with high chill requirements.

3.1.6 Avocados

Avocados require warm spring conditions with ideal average maximum temperatures exceeding 15, 16 and 17°C for the months of September, October and November. These requirements are not met in the coastal area north of Kaikoura for September (Table 8), and only just met in October and November.

As well, especially for effective flowering, the average minimum temperatures for September, October and November should exceed 8, 9 and 10°C. These criteria are never met at either of the VCSN locations.

In addition, for avocados, the mean extreme temperature should ideally always be above 0°C. This criterion is not met at either location.

Table 7. Temperature criteria for avocados for the Virtual Climate Station Network (VCSN) stations 28071 and 30703 for the region north of Kaikoura.

VCSN	28071	30703	Ideal
Mean maximum temperature in September	14.8°C	14.6°C	>15°C
Mean maximum temperature in October	16.8°C	16.6°C	>16°C
Mean maximum temperature in November	18.6°C	18.6°C	>17°C
Mean minimum temperature in September	6.2°C	6°C	>8°C
Mean minimum temperature in October	7.5°C	7.5°C	>9°C
Mean minimum temperature in November	9.2°C	9.2°C	>10°C
Mean annual extreme minimum temperature	-0.3°C	-1.2°C	> 0°C

The coastal region north of Kaikoura is not well suited to avocados because the temperatures in spring and winter are generally too cool.

3.2 Around Kaikoura

For the area around Kaikoura, on the peninsula plain, we have associated three VCSN locations. These are VCSN 20420 along the Inland Road, plus VCSN 28055, along the coastal area of the Kaikoura plains, and VCSN 29086, for the inland area of the Kaikoura peninsula plain (Figure 1).

The general climate statistics for these three VCSN stations are presented in Table 9. The VCSN data for stations 28055 and 29086 show there are no days when the temperature dropped below -2°C.

Table 8. General climate statistics for the Virtual Climate Station Network (VCSN) stations 20420, 28055 and 29086 for the region around Kaikoura on the peninsula plain.

VCSN	20420	28055	29086
Chill hours, April-September (T < 7°C)			
Mean	1955	1329	1467
20th percentile	1729	1117	1272
46-year minimum	1440	855	980
Chill hours, April-September (T < 7.2°C)			
Mean	2038	1412	1550
20th percentile	1812	1210	1352
46-year minimum	1542	932	1045
Growing Degree Days base 10°C, October-April			
Mean	794	998	953
20th percentile	716	924	886
46-year minimum	576	737	700
Spring and autumn frosts (0°C)			
Mean date of first autumn frost	June 13	June 30	July 7
20th percentile first autumn frost	May 24	June 11	June 13
46-year earliest frost	April 19	May 25	May 24
Mean date of last spring frost	August 29	July 18	July 28
80th percentile last spring frost	September 11	August 9	August 16
46-year latest frost	November 12	September 1	September 30
Mean frost-free period	288 days	343 days	348 days
20th percentile frost-free period	254 days	316 days	308 days
46-year minimum frost-free period	187 days	305 days	280 days
Spring and autumn frosts (-2°C)			
Mean date of first autumn frost	July 1	-	-
20th percentile first autumn frost	June 11	-	-
46-year earliest frost	May 25	-	-
Mean date of last spring frost	July 19	-	-
80th percentile last spring frost	August 8	-	-
46-year latest frost	September 1	-	-
Mean frost-free period	352 days	-	-
20th percentile frost-free period	328 days	-	-
46-year minimum frost-free period	300 days	-	-

3.2.1 Apples

Around Kaikoura there is sufficient winter chill for apples, with the chill hours of between 1400 and 2040 hours (Table 9) well exceeding the 500 chill hours at less than 7.2°C that are required by apples.

There is sufficient warmth in the GDD_{10} from October-April for VCSN 28055 (998 degree days) and 29086 (953 degree days) for apples, which need over 800 degree days. But at VCSN 20420 (794 degree days) the summer GDD_{10} is on the limit (Table 9). There is sufficient spring GDD_{10} for the first 50 days after flowering for all stations of between 155 and 186 degree days, exceeding the 120 required by apples.

There is a small frost risk for apples at VCSN 20420 on the Inland Road. This seems counter-intuitive, but the frost risk here is less the that nearer the coast because the spring GDD_{10} is lower, meaning that the flowering date and harvest date are generally a week or so later than those nearer the coast (Table 10). Substantial frost protection measures would be required for apples at VCSN stations 28055 and 29086 on the Kaikoura peninsula plains.

Table 9. Apple growing criteria for the Virtual Climate Station Network (VCSN) stations 20420, 28055 and 29086 for the region around Kaikoura on the peninsula plain.

VCSN	20420	28055	29086
Mean date of apple flowering	October 28	October 22	October 23
Probability of frost after flowering	4%	60%	34%
Mean date of apple harvesting	April 8	March 28	March 31
Probability of frost before harvest	2%	60%	34%
Mean GDD_{10} for the first 50 days after flowering	155	186	178

The peninsula plain around Kaikoura appears well suited to apple growing, as long as frost protection measures were taken.

3.2.2 Kiwifruit

For kiwifruit on the peninsula plain around Kaikoura there is sufficient winter chilling. The mean temperatures between May to July for the three VCSN stations are shown in Table 11, and they are all less than the 11.7-15°C required by kiwifruit, depending on cultivar, and whether or not Hi-Cane is applied.

However in terms of summer GDD_{10}, the values on the plain of 794-998 degree days (Table 9) are all less than the 1100 hours required by kiwifruit.

Whereas it would be reasonably possible to mitigate the frost risk at VCSN 20420 on the Inland Road, substantial frost protection measures would be required for kiwifruit at VCSN locations 28055 and 29086 on the Kaikoura peninsula plains.

Table 10. Kiwifruit growing criteria for the Virtual Climate Station Network (VCSN) stations 20420, 28055 and 29086 for the region around Kaikoura on the peninsula plain.

VCSN	20420	28055	29086
Mean temperature from May to July	7.6°C	9.1°C	8.8°C
Mean date of green kiwifruit budbreak	September 12	September 16	September 14
Probability of frost after budbreak (green-fleshed kiwifruit)	19%	60%	36%
Mean date of gold kiwifruit budbreak	September 12	September 15	September 14
Probability of frost after budbreak (gold-fleshed kiwifruit)	19%	60%	36%

There appears to be insufficient summer warmth on the peninsula plain around Kaikoura for the successful growing of kiwifruit.

3.2.3 Wine grapes (Pinot noir and Sauvignon blanc)

For growing grapes on the peninsula plain around Kaikoura there is sufficient winter chill, with the mean July temperatures being less than 7.8°C, meeting the criterion for grapes of a mean July temperature of less than 12°C (Table 12).

There is no frost risk in spring, and no risk of excessive summer heat greater than 40°C (Table 12).

There are autumn rains of over 90 mm per month for March and April (Table 12), whereas for grapes ideally there should be less than 70 mm per month in autumn. Care would need to be taken to avoid berry splitting and botrytis bunch rot late in the season. By way of reference, in the grape-growing region of Waipara to the south, the average monthly rainfall for March and April is just 55 mm per month, well less than our criterion.

The grape growing season warmth of over 900 degree days for VCSN locations 29086 and 28055 are sufficient for Pinot noir (800-1000) and for Sauvignon blanc (850-1050). However, the summer GDD_{10} of about 710 for VCSN 20420 on the Inland Road would appear to make this marginal for grape growing.

Table 11. Wine grape growing criteria for the Virtual Climate Station Network (VCSN) stations 20420, 28055 and 29086 for the region around Kaikoura on the peninsula plain.

VCSN	20420	28055	29086
Mean temperature in July	6.3°C	7.8°C	7.5°C
Mean monthly rainfall for March and April	95.9mm	92.6mm	93.2mm
Mean number of summer days with maximum temperature above 40°C	0	0	0
Mean autumn date where temperatures drop below 13°C	March 29	April 16	April 13
Mean budbreak date for Pinot noir	October 9	October 5	October 6
Mean GDD_{10} for Pinot noir growing season	717	958	905
Mean budbreak date for Sauvignon blanc	October 12	October 7	October 8
Mean GDD_{10} for Sauvignon blanc growing season	714	954	902
Risk of -1°C frost after budbreak (Pinot noir)	0%	0%	0%
Risk of -3°C frost after budbreak (Pinot noir)	0%	0%	0%
Risk of -1°C frost after budbreak (Sauvignon blanc)	0%	0%	0%
Risk of -3°C frost after budbreak (Sauvignon blanc)	0%	0%	0%

Grape growing would appear suitable for the coastal parts of the peninsula plain around Kaikoura, although care would need to be taken with management of the autumnal rains.

3.2.4 Blueberries

For blueberry growing on the peninsula plain around Kaikoura there is sufficient winter chill of greater than 800 chill hours at less than 7.2°C (Table 13).

There is sufficient summer warmth, with the GDD_{10} being greater than 794 degree days, and exceeding the GDD_{10} of 600 degree days required by blueberries.

However, peak summer temperatures are cool, with at least about 30 days over the summer where the maximum temperature is less than 18-19°C. This would seem to exceed the ability of protected coverings to mitigate the lack of ambient warmth.

Table 12. Summer maximum daily temperature criteria for blueberry growing for the Virtual Climate Station Network (VCSN) stations 20420, 28055 and 29086 for the region around Kaikoura on the peninsula plain.

VCSN	20420	28055	29086
Percentage of years with at least one summer day with maximum temperature less than 18°C	100%	100%	100%
80^{th} percentile of summer days with maximum temperature less than 18°C	35	32	32
Percentage of years with at least one summer day with maximum temperature less than 19°C	100%	100%	100%
80^{th} percentile of summer days with maximum temperature less than 19°C	47	43	43

It would seem that the lack of high summer temperatures on the peninsula plain around Kaikoura would render the area marginal for growing blueberries, even under protected covers.

3.2.5 Hazelnuts and walnuts

For VCSN 20420 on the inland Road the winter chill requirements are always met for hazelnuts (>1200 hours at <7°C) and mostly for walnuts (>400-1600 hours at <7°C) depending on cultivar (Table 14). The summer warmth there is marginal for nuts, with a GDD_{10} of 794 degree days, for nut crops require more than 800 degree days (Table 9).

For VCSN locations 28055 and 20986 on the Kaikoura plains there is sufficient winter chill for hazelnuts, and for walnuts with low to moderate chilling requirements. There is sufficient summer warmth, with the GDD_{10}s being 953 and 998 degree days (Table 9).

There are few risks from spring and autumn frosts of more than -2°C (Table 14).

Table 13. Chill hour and frost risk criteria for hazelnuts and walnuts for the Virtual Climate Station Network (VCSN) stations 20420, 28055 and 29086 for the region around Kaikoura on the peninsula plain.

VCSN	20420	28055	29086
Probability of >400 winter chill hours	100%	100%	100%
Probability of >800 winter chill hours	100%	100%	100%
Probability of >1200 winter chill hours	100%	70%	87%
Probability of >1600 winter chill hours	91%	11%	30%
Probability of autumn frost before March 15	0%	0%	0%
Probability of spring frost after October 15	0%	0%	0%
Probability of spring frost after November 1	0%	0%	0%

The Kaikoura peninsula appear suitable for growing hazelnuts and walnuts, especially walnuts with low chilling requirements.

3.2.6 Avocados

On the Inland Road (VCSN 20420) there is insufficient warmth in summer for successfully growing avocados (Table 15). As well, the extreme temperature in winter of -17°C is not ideal (Table 15).

At the other two VCSN stations on the peninsula plain (28055 and 29086), the ideal criteria for avocado growing in relation to maximum summer temperatures are only just met (Table 15). The minimum temperature criteria are never quite realised.

Table 14. Temperature criteria for avocados for the Virtual Climate Station Network (VCSN) stations 20420, 28055 and 29086 for the region around Kaikoura on the peninsula plain.

VCSN	20420	28055	29086	Ideal
Mean maximum temperature in September	13.7°C	15.3°C	15°C	>15°C
Mean maximum temperature in October	15.8°C	17.8°C	16.9°C	>16°C
Mean maximum temperature in November	17.5°C	19.0°C	18.7°C	>17°C
Mean minimum temperature in September	4.7°C	6.3°C	6°C	>8°C
Mean minimum temperature in October	6.1°C	7.7°C	7.3°C	>9°C
Mean minimum temperature in November	7.8°C	9.3°C	9°C	>10°C
Mean annual extreme minimum temperature	-1.7°C	0.2°C	-0.2°C	>0°C

It would appear that the peninsula plain around Kaikoura is marginal for the successful growing of avocados.

3.3 Waiau and surrounds

In the Waiau basin and surrounds we consider two VCSN locations. The VCSN 20367 is near Lyford, and the VCSN location 20370 is near Waiau itself.

Table 15. General climate statistics for the Virtual Climate Station Network (VCSN) stations 20367 and 20370 for the region of Waiau and surrounds.

VCSN	20367	20370
Chill hours, April-September (T < 7°C)		
Mean	2425	1871
20th percentile	2233	1711
46-year minimum	1940	1419
Chill hours, April-September (T < 7.2°C)		
Mean	2494	1942
20th percentile	2291	1778
46-year minimum	2017	1495
Growing Degree Days base 10°C, October-April		
Mean	695	955
20th percentile	602	872
46-year minimum	442	722
Spring and autumn frosts (0°C)		
Mean date of first autumn frost	May 7	May 29
20th percentile first autumn frost	April 21	May 11
46-year earliest frost	March 17	April 19
Mean date of last spring frost	October 11	September 12
80th percentile last spring frost	October 25	September 27
46-year latest frost	December 1	November 12
Mean frost-free period	208 days	259 days
20th percentile frost-free period	185 days	244 days
46-year minimum frost-free period	106 days	179 days
Spring and autumn frosts (-2°C)		
Mean date of first autumn frost	June 6	June 24
20th percentile first autumn frost	May 23	June 4
46-year earliest frost	April 19	May 23
Mean date of last spring frost	September 5	August 2
80th percentile last spring frost	September 22	August 25
46-year latest frost	November 12	October 6
Mean frost-free period	273 days	325 days
20th percentile frost-free period	250 days	295 days
46-year minimum frost-free period	179 days	259 days

3.3.1 Apples

For Waiau and surrounds there is sufficient winter chill for growing apples, with at least 1900 hours less than 7.2°C (Table 16), which exceeds the requirements for apple of 500 hours.

The summer GDD_{10} from October-April is 955 degree days at VCSN 20370 (Waiau) (Table 16), which is greater than the apple criterion of 800. But at VCSN 20367 (Lyford), the summer GDD_{10} is just 695 degree days, making it marginal for apples. Both stations exceed the apple criterion for GDD_{10} for the first 50 days after flowering, of 120 degree days. These GDD_{10} values are 137 (Lyford) and 171 (Waiau) (Table 17).

There is little risk of frost for VCSN 20370 (Waiau), but some frost protection would be needed for VCSN 20367 (Lyford) (Table 17).

Table 16. Apple growing criteria for the Virtual Climate Station Network (VCSN) stations 20367 and 20370 for the region of Waiau and surrounds.

VCSN	20367	20370
Mean date of apple flowering	October 30	October 20
Probability of frost after flowering	17%	2%
Mean date of apple harvesting	April 14	March 22
Probability of frost before harvest	15%	0%
Mean GDD_{10} for the first 50 days after flowering	137	171

In the Waiau basin apple growing would be possible at Waiau (VCSN 20370), but marginal at Lyford (VCSN 20367).

3.3.2 Kiwifruit

For kiwifruit in the Waiau and surrounds there is sufficient winter chill for kiwifruit, with the mean winter temperatures from May to July being just 6.2°C and 7.8°C (Table 18). This is less than that 11.7-15°C required for kiwifruit depending on cultivar, and whether or not Hi-Cane is applied.

Kiwifruit require a summer GDD_{10} exceeding 1100 degree days. Neither VCSN station achieves this (Table 16). Furthermore there is a high risk of frost after bud-break (Table 18), being about 40% at Waiau and 90% at Lyford.

Table 17. Kiwifruit growing criteria for the Virtual Climate Station Network (VCSN) stations 20367 and 20370 for the region of Waiau and surrounds.

VCSN	20367	20370
Mean temperature from May to July	6.2°C	7.8°C
Mean date of green kiwifruit budbreak	September 11	September 12
Probability of frost after budbreak (green-fleshed kiwifruit)	91%	43%
Mean date of gold kiwifruit budbreak	September 10	September 13
Probability of frost after budbreak (gold-fleshed kiwifruit)	91%	41%

The Waiau basin and surrounds are not suitable for growing kiwifruit, as it is generally too cold, and there is a high risk of frost after budbreak.

3.3.3 Wine grapes (Pinot noir and Sauvignon blanc)

For grape growing in the Waiau basin there is sufficient winter chill, as the mean July temperatures are less than 7.5°C, being less than the requirement for grapes of 12°C (Table 19). There is a low risk of a frost of -1°C for Pinot noir in spring at VCSN 20367; otherwise there is very little risk. Also, there is very little risk of excessive summer heat of greater than 40°C.

There is excessive autumn rain for VCSN 20367 (Lyford), at 108.9 mm per month (Table 19), whereas at VCSN 20370 (Waiau) the rainfall is less than the grape criterion of 70 mm per month.

The summer GDD_{10} at VCSN 20370 is about 890 degree days (Table 19), which is at the lower end of the range for Pinot noir (800-1000), and for Sauvignon blanc (850-1050). At VCSN 20367, the summer GDD_{10} is too low for both grape varieties (Table 19).

Table 18. Wine grape growing criteria for the Virtual Climate Station Network (VCSN) stations 20367 and 20370 for the region of Waiau and surrounds.

VCSN	20367	20370
Mean temperature in July	7.5°C	6.5°C
Mean monthly rainfall for March and April	108.9mm	65.6mm
Mean number of summer days with maximum temperature above 40°C	0	0
Mean autumn date where temperatures drop below 13°C	March 20	April 8
Mean budbreak date for Pinot noir	October 13	October 7
Mean GDD_{10} for Pinot noir growing season	614	896
Mean budbreak date for Sauvignon blanc	October 17	October 9
Mean GDD_{10} for Sauvignon blanc growing season	610	894
Risk of -1°C frost after budbreak (Pinot noir)	13%	0%
Risk of -3°C frost after budbreak (Pinot noir)	10%	0%
Risk of -1°C frost after budbreak (Sauvignon blanc)	0%	0%
Risk of -3°C frost after budbreak (Sauvignon blanc)	0%	0%

In the Waiau basin it would be possible to grow grapes at Waiau itself (VCSN 20370), but at VCSN 20367 (Lyford) it would not be suitable for grape growing.

3.3.4 Blueberries

For growing blueberries in the Waiau basin there is sufficient winter chill, with there being over 1940 chill hours of temperatures less 7.2°C, more than the 800 hours required by blueberries (Table 20).

The summer warmth of GDD_{10} exceeds 695 degree days in the Waiau basin, which is above the requirement 600 degree days for blueberries (Table 20).

However, peak summer temperatures are too cool for the ideal conditions for blueberries, as there is usually for at least three weeks to a month over the summer when the maximum daily temperature is less than 18-19°C. These absences of high temperatures might be too great to be mitigated through the use of tunnel houses or protective shelters.

Table 19. Summer maximum daily temperature criteria for blueberry growing for the Virtual Climate Station Network (VCSN) stations 20367 and 20370 for the region of Waiau and surrounds.

VCSN	20367	20370
Percentage of years with at least one summer day with maximum temperature less than 18°C	100%	100%
80th percentile of summer days with maximum temperature less than 18°C	32	23
Percentage of years with at least one summer day with maximum temperature less than 19°C	100%	100%
80th percentile of summer days with maximum temperature less than 19°C	42	29

It would seem to be too cool here for the successful growing of blueberries, even under covered production.

3.3.5 Hazelnuts and walnuts

For nut crops, there is sufficient winter chilling in the Waiau basin, with the chill hours being 1871 (VCSN 20370) and 2425 (VCSN 20367). These hours generally exceed the winter chill requirement for hazelnuts (>1200 hours) and walnuts (>400-1600 hours) (Table 21).

The summer GDD_{10}s at the two VCSN locations are 695 degree days (VCSN 20367) and 955 degree days (VCSN 955) (Table 16). Only the latter location (Waiau) exceeds the nut-growing criterion of 800 degree days.

There is a very low risk of spring or autumn frosts of greater than -2°C (Table 21).

Table 20. Chill hour and frost risk criteria for hazelnuts and walnuts for the Virtual Climate Station Network (VCSN) stations 20367 and 20370 for the region of Waiau and surrounds.

VCSN	20367	20370
Probability of >400 winter chill hours	100%	100%
Probability of >800 winter chill hours	100%	100%
Probability of >1200 winter chill hours	100%	100%
Probability of >1600 winter chill hours	100%	87%
Probability of autumn frost before March 15	0%	0%
Probability of spring frost after October 15	2%	0%
Probability of spring frost after November 1	2%	0%

For the Waiau basin, the Waiau site is suitable for growing nuts, but the low summer warmth at the Lyford site makes it marginal for nut crops.

3.3.6 Avocados

Avocados ideally require warm maximum temperatures in September (15°C), October (16°C), and November (17°C). These conditions are not met at VCSN 20367, whereas they are (or nearly are) at VCSN 20370. Also, avocados ideally require warm minimum temperatures over September (8°C), October (9°C) and November (10°C). These condition are not met at either site (Table 22). As well, the presence of frosts is not ideal for avocados here (Table 22).

Table 21. Temperature criteria for avocados for the Virtual Climate Station Network (VCSN) stations 20367 and 20370 for the region of Waiau and surrounds.

VCSN	20367	20370	Ideal
Mean maximum temperature in September	127°C	14.8°C	>15°C
Mean maximum temperature in October	15.0°C	17.0°C	>16°C
Mean maximum temperature in November	17.0°C	18.8°C	>17°C
Mean minimum temperature in September	3.2°C	4.7°C	>8°C
Mean minimum temperature in October	4.7°C	6.2°C	>9°C
Mean minimum temperature in November	6.3°C	7.9°C	>10°C
Mean annual extreme minimum temperature	-4.2°C	-2.7°C	>0°C

The Waiau basin and surrounds are considered unsuitable for the growing of avocados.

3.4 Cheviot and Conway Flat

Three VCSN locations were used to characterise the climate of Cheviot and the Conway Flat. These were VCSN 20342 in the Leader Valley; VCSN 20344 north of Cheviot along Parnassus Road, plus VCSN 20694 on the Conway Flat. The VCSN climate statistics are presented in Table 23.

Again we have anomalous frost free period (FFP) values longer than a year, for frosts of greater than -2°C. This artefact is because there are very few years with frosts that cold, and when that happens for two consecutive years, the frost in the second year is often later than the frost in the first year.

Table 22. General climate statistics for the Virtual Climate Station Network (VCSN) stations 20342, 20344 and 20694 for Cheviot and the Conway Flat.

VCSN	20342	20344	20694
Chill hours, April-September (T < 7°C)			
Mean	1761	1553	1818
20th percentile	1596	1368	1634
46-year minimum	1253	1062	1225
Chill hours, April-September (T < 7.2°C)			
Mean	1842	1631	1903
20th percentile	1682	1454	1719
46-year minimum	1351	1142	1320
Growing Degree Days base 10°C, October-April			
Mean	926	1017	831
20th percentile	839	934	752
46-year minimum	691	770	620
Spring and autumn frosts (0°C)			
Mean date of first autumn frost	June 11	June 19	June 22
20th percentile first autumn frost	May 24	June 2	June 2
46-year earliest frost	April 19	May 23	May 18
Mean date of last spring frost	August 24	August 12	August 22
80th percentile last spring frost	September 10	August 30	September 8
46-year latest frost	November 12	October 6	November 12
Mean frost-free period	290 days	309 days	301 days
20th percentile frost-free period	259 days	286 days	275 days
46-year minimum frost-free period	187 days	238 days	187 days
Spring and autumn frosts (-2°C)			
Mean date of first autumn frost	July 4	July 1	July 6
20th percentile first autumn frost	June 17	June 14	June 8
46-year earliest frost	June 7	June 7	May 25
Mean date of last spring frost	July 18	July 17	July 18
80th percentile last spring frost	July 30	July 30	August 11
46-year latest frost	September 1	August 1	September 1
Mean frost-free period	363 days	369 days	384 days
20th percentile frost-free period	334 days	369 days	375 days
46-year minimum frost-free period	326 days	369 days	369 days

3.4.1 Apples

For apples in the Cheviot region and the Conway Flat there is sufficient winter chilling, as the number of hours less than 7.2°C between April and September is greater than 1550 hours (Table 24). Apples require only 500 chill hours.

The summer warmth of the GDD_{10} between October and April is above 830 degree days for all sites (Table 24), and this exceeds the apple criterion of 800 hours, but only just, on average, at Conway Flat. Also, there are sufficient GDD_{10} for the first 50 days after flowering for all locations, as the value exceeds the apple criterion of 120 degree days (Table 24).

At all the sites there is an acceptable frost risk, although some frost protection may be needed (Table 24).

Table 23. Apple growing criteria for the Virtual Climate Station Network (VCSN) stations 20342, 20344 and 20694 for Cheviot and the Conway Flat

VCSN	20342	20344	20694
Mean date of apple flowering	October 22	October 19	October 27
Probability of frost after flowering	8%	17%	19%
Mean date of apple harvesting	March 31	March 26	April 7
Probability of frost before harvest	6%	17%	17%
Mean GDD_{10} for the first 50 days after flowering	170	184	162

The Cheviot and Parnassus basins appear well suited for growing apples. Because of the marginal summer warmth at Conway Flat, low GDD_{10} apple cultivars would be needed.

3.4.2 Kiwifruit

There is sufficient winter chill at all sites, as the mean May to July temperature is below11.7-15°C, the requirement for kiwifruit, depending on cultivar and whether or not Hi-Cane is applied (Table 25).

However, there is insufficient summer warmth, as the GDD_{10} values are all less than 1017 degree days (Table 23), whereas kiwifruit require at least 1100 degree days.

As well, there is a moderate degree of frost risk (Table 25), so frost protection would be needed.

Table 24. Kiwifruit growing criteria for the Virtual Climate Station Network (VCSN) stations 20342, 20344 and 20694 for Cheviot and the Conway Flat.

VCSN	20342	20344	20694
Mean temperature from May to July	8.1°C	8.7°C	8°C
Mean date of green kiwifruit budbreak	September 13	September 14	September 12
Probability of frost after budbreak (green-fleshed kiwifruit)	21%	21%	30%
Mean date of gold kiwifruit budbreak	September 13	September 14	September 13
Probability of frost after budbreak (gold-fleshed kiwifruit)	21%	21%	30%

The Cheviots and Parnassus basins, along with the Conway Flat, appear unsuited for growing kiwifruit.

3.4.3 Wine grapes (Pinot noir and Sauvignon blanc)

For grape growing in the Cheviot and Parnassus basin, plus the Conway Flat, the mean July temperatures are less than 7.4°C (Table 26), which means there is sufficient winter chilling, as these temperatures are lower than the criterion 12°C. There is little frost risk in spring, and there is no risk of excessive summer heat greater than 40°C.

There are, however, higher than ideal autumn rains, of between 74 and 99 mm per month in March and April. Ideally this should be less than 70 mm per month for March and April (Table 26).

For grapes there should be a warm growing season with a GDD_{10} of 800-1000 degree days for Pinot noir, and 850-1050 for Sauvignon blanc. The warmth is just achieved in the Leader Valley and Cheviot, but not on the Conway Flat.

Table 25. Wine grape growing criteria for the Virtual Climate Station Network (VCSN) stations 20342, 20344 and 20694 for Cheviot and the Conway Flat.

VCSN	20342	20344	20694
Mean temperature in July	6.8°C	7.4°C	6.7°C
Mean monthly rainfall for March and April	98.8mm	73.9mm	83.0mm
Mean number of summer days with maximum temperature above 40°C	0	0	0
Mean autumn date where temperatures drop below 13°C	April 7	April 14	April 2
Mean budbreak date for Pinot noir	October 7	October 5	October 8
Mean GDD_{10} for Pinot noir growing season	864	973	758
Mean budbreak date for Sauvignon blanc	October 9	October 8	October 11
Mean GDD_{10} for Sauvignon blanc growing season	862	968	755
Risk of -1°C frost after budbreak (Pinot noir)	0%	0%	0%
Risk of -3°C frost after budbreak (Pinot noir)	0%	0%	0%
Risk of -1°C frost after budbreak (Sauvignon blanc)	0%	0%	0%
Risk of -3°C frost after budbreak (Sauvignon blanc)	0%	0%	0%

The Cheviot Basin and Leader Valley of Parnassus are marginal for grapes, because of the autumn rains and a lack of significant summer warmth. Grapes would appear unsuitable for the Conway Flat.

3.4.4 Blueberries

For growing blueberries in the Cheviot Basin and Leader Valley near Parnassus, and on the Conway Flat, there is sufficient winter chill, with there being over 1630 chill hours of temperatures less than 7.2°C, more than the 800 hours required by blueberries (Table 23).

The summer warmth of GDD_{10} exceeds 830 degree days across all three VCSN locations, which is above the requirement 600 degree days for blueberries (Table 23.

However, peak summer temperatures are too cool for ideal conditions for blueberries, as there is usually for at least three weeks to a month over the summer when the maximum daily temperature is less than 18-19°C (Table 27). These absences of high temperatures might be too great to be mitigated through the use of tunnel houses or crop protection shelters.

Table 26. Summer maximum daily temperature criteria for blueberry growing for the Virtual Climate Station Network (VCSN) stations 20342, 20344 and 20694 for Cheviot and the Conway Flat.

VCSN	20342	20344	20694
Percentage of years with at least one summer day with maximum temperature less than 18°C	100%	100%	100%
80th percentile of summer days with maximum temperature less than 18°C	27	24	36
Percentage of years with at least one summer day with maximum temperature less than 19°C	100%	100%	100%
80th percentile of summer days with maximum temperature less than 19°C	36	32	45

Blueberry production does not appear feasible for the Cheviot Basin, Leader Valley or the Conway Flat.

3.4.5 Hazelnuts and walnuts

In the Cheviot Basin, Leader Valley, and Conway Flat there is sufficient winter cooling for hazelnuts and walnuts with low-moderate chill requirements of greater than 1200 chill hours (Table 28). Even VCSN locations 20342 and 20694 have almost sufficient winter chilling for walnuts with high chill requirements of 1600 hours (Table 28).

The summer warmth requirement for nuts of a GDD_{10} greater than 800 degree days is met at VCSN stations 20342 and 20344, but it is marginal at VCSN station 20694 for the Conway Flat (Table 23).

There is very little risk of spring and autumn frosts heavier than -2°C at any station.

Table 27. Chill hours and frost risk criteria for hazelnuts and walnuts for the Virtual Climate Station Network (VCSN) stations 20342, 20344 and 20694 for Cheviot and the Conway Flat.

VCSN	20342	20344	20694
Probability of >400 winter chill hours	100%	100%	100%
Probability of >800 winter chill hours	100%	100%	100%
Probability of >1200 winter chill hours	100%	93%	100%
Probability of >1600 winter chill hours	78%	48%	83%
Probability of autumn frost before March 15	0%	0%	0%
Probability of spring frost after October 15	0%	0%	0%
Probability of spring frost after November 1	0%	0%	0%

The Cheviot Basin and the Leader Valley near Parnassus are suitable for growing nuts, although they would appear marginal for the Conway Flats because of a lack of summer warmth.

3.4.6 Avocados

Avocados require warm maximum temperatures in September (15°C), October (16°C), and November (17°C). These conditions are met, or very nearly met at all three VCSN stations (Table 29). Also, avocados ideally require warm minimum temperatures over September (8°C), October (9°C) and November (10°C). These condition are not met at any site (Table 29). As well, the presence of frosts here is not ideal for avocados (Table 29).

Table 28. Temperature criteria for avocados for the Virtual Climate Station Network (VCSN) stations 20342, 20344 and 20694 for Cheviot and the Conway Flat.

VCSN	20342	20344	20694	Ideal
Mean maximum temperature in September	14.7°C	15.5°C	14.4°C	>15°C
Mean maximum temperature in October	16.9°C	17.6°C	16.4°C	>16°C
Mean maximum temperature in November	18.6°C	19.3°C	18.1°C	>17°C
Mean minimum temperature in September	5.1°C	5.7°C	5.1°C	>8°C
Mean minimum temperature in October	6.5°C	7.1°C	6.4°C	>9°C
Mean minimum temperature in November	8.2°C	8.7°C	8°C	>10°C
Mean annual extreme minimum temperature	-1.6°C	-1°C	-1.1°C	>0°C

None of these locations appear suitable for growing avocados.

4 Conclusions

We first carried out a generic assessment of the suitability of the Post-Quake Agriculture Project's area for horticultural crops. These generic criteria reveal that potentially there are 41,515 ha of land that would be suitable for horticulture.

We then used VCSN data of long-term weather records to provide a detailed assessment of six horticultural crops across four sub-regions in the Post-Quake Project area.

We associated two, or three, VCSN locations with each sub-region. This stratification included:

- North of Kaikoura – VCSN 30703, 28071
- Kaikoura plains – VCSN 20420, 29086, 28055
- Waiau and surrounds – VCSN 20367, 20370
- Cheviot and Conway flat – VCSN 20342, 20694, 20344.

For each sub-region, the associated VCSN data were used to assess suitability of the following crops:

- Apples
- Kiwifruit
- Wine grapes
- Blueberries
- Hazelnuts and walnuts
- Avocados.

For these sub-regions, the crops that we consider suitable are:

- North of Kaikoura – apples, grapes, hazelnuts and walnuts
- Kaikoura plains – apples, grapes (coastal), hazelnuts and walnuts
- Waiau and surrounds – apples (Waiau only), grapes (Waiau only), hazelnuts and walnuts
- Cheviot and Conway flat – apples, hazelnuts and walnuts.

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